Explosives-Contaminated Groundwater:
Fate / Transport and USACE Remedial Action Experience

Charles G. Coyle P.E.

U.S. Army Corps of Engineers

HTRW Center of Expertise

E-mail: charles.g.coyle@usace.army.mil

Phone: 402-697-2578

Fax: 402-697-2595

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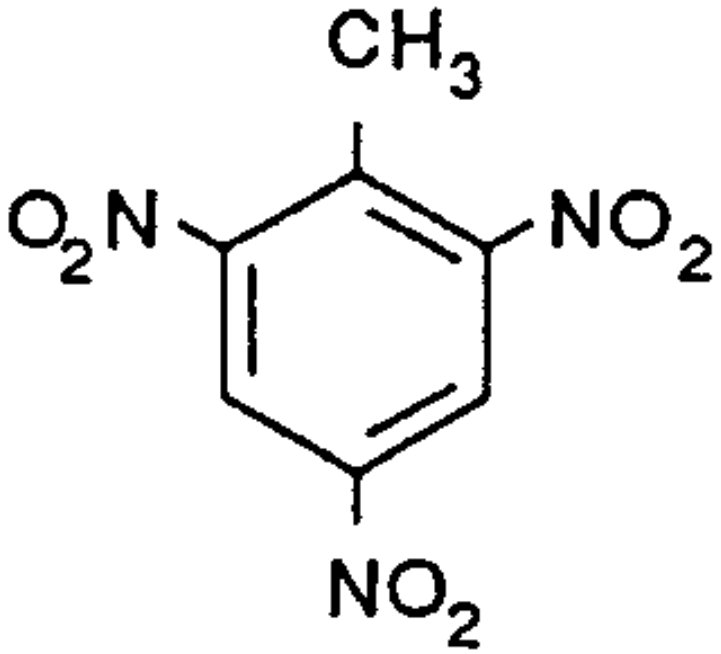
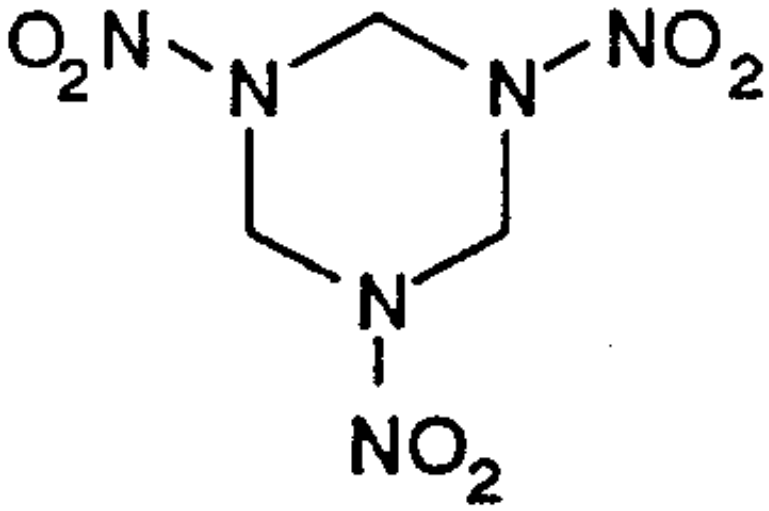
Overview

- Properties of TNT & RDX
- Fate & Transport
- Remedial Action Alternatives
  - Ex-Situ Treatment Processes
  - Natural Attenuation
- Groundwater Remediation Project Experience

Chemical Structures



TNT
(2,4,6-trinitrotoluene)



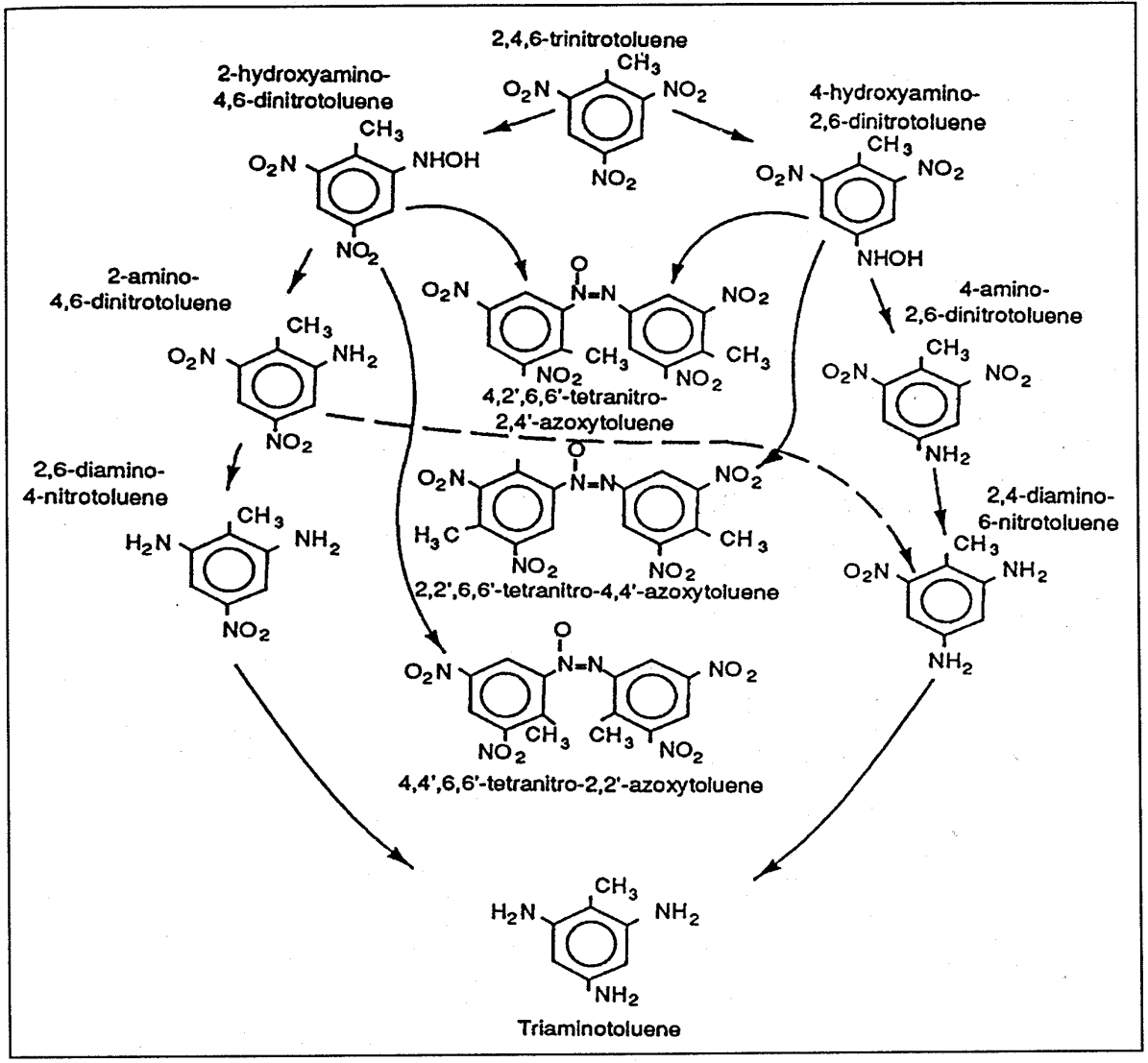
RDX
(hexahydro-1,3,5-trinitro-1,3,5-triazine)

Fate & Transport

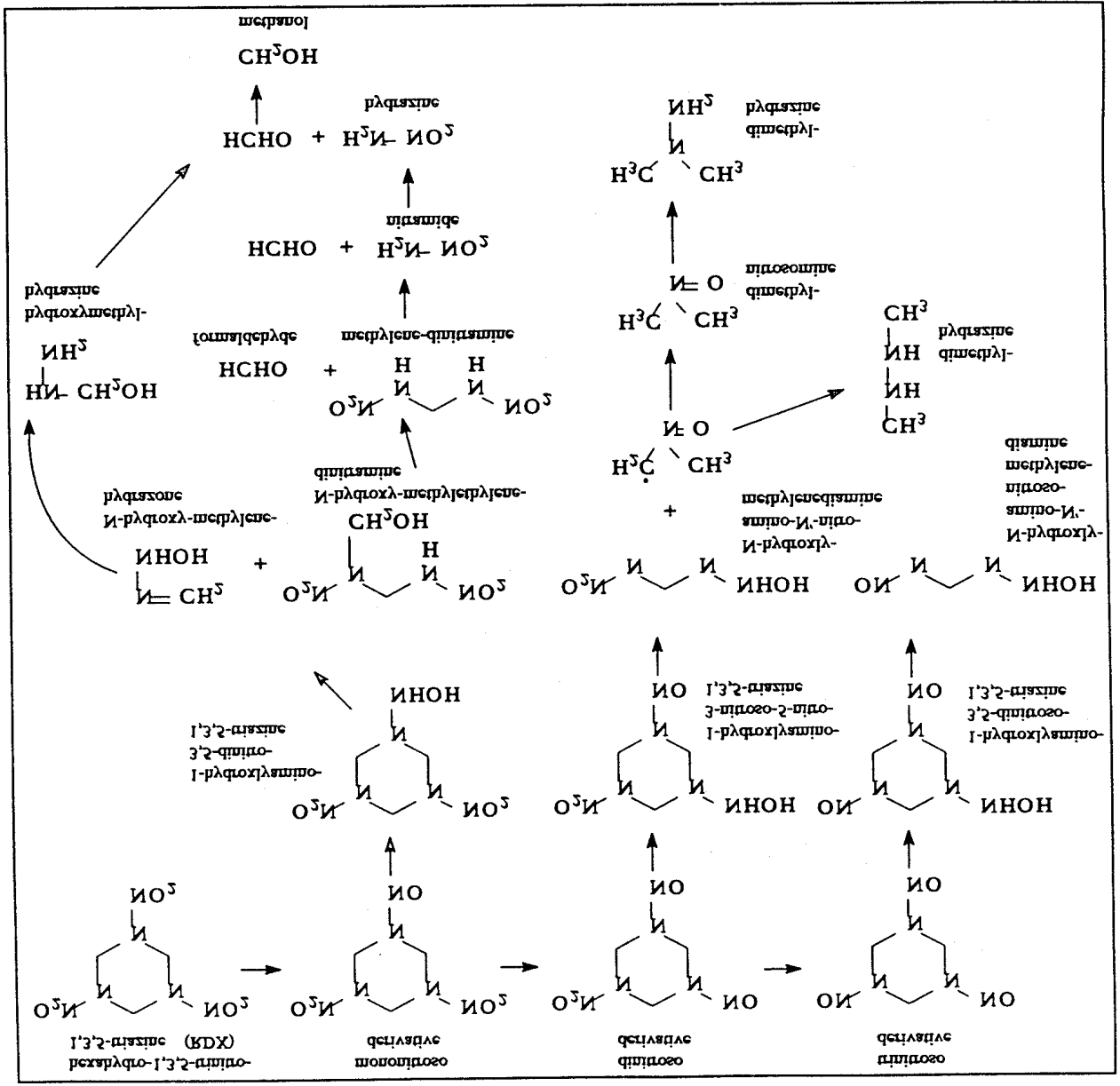
- photolysis
- infiltration
- advection, dispersion, adsorption, diffusion
- biotic transformation
- covalent bonding

Transformation Pathways

- **TNT**
  - **2-Amino-4,6-DNT (most commonly detected transformation product)**
- **RDX**



•From Myers, T.E.,Brannon, J.M., Pennington, J.C., Townsend, D.M., Davis, W.M., Ochman, M.K., Hayes, C.A., and Myers, K.F. (1998). "Laboratory studies of soil sorption/transformation of TNT, RDX, and HMX," Technical Report IRRP-98-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.; modified from From McGrath, C.J. (1995). "Review of formulations for processes affecting the subsurface transport of explosives," Technical Report IRRP-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.; modified from Kaplan, D.L. (1993). "Biotechnology and bioremediation for organic energetic compounds." Organic energetic



•From McGrath, C.J. (1995). “Review of formulations for processes affecting the subsurface transport of explosives,” Technical Report IRRP-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.; after Kaplan, D.L. (1993). “Biotechnology and bioremediation for organic energetic compounds.” Organic energetic compounds. P. Marinkas, ed., Nova Science Publication, Inc. , New York, pp 123-5.

Fate & Transport

TNT vs. RDX

- Amino transformation products
- may become irreversibly bound
- less mobile

- Not readily transformed
- doesn’t enter into covalent bonding
- more mobile

Remedial Action Alternatives

- **Ex-Situ (pump & treat)**
- **Natural Attenuation**
- **In Situ Treatment**

Remedial Action Alternatives

- **Ex-Situ (pump & treat)**
  - **Activated Carbon**
  - **Advanced Oxidation Processes**

USACE Groundwater Remediation Experience

- Umatilla Depot Activity
- Milan AAP
- Cornhusker AAP
- Louisiana AAP

Costs of Alternatives

Ex-Situ

- Milan AAP 1999
- 600 gpm, extraction/injection
  - UV Oxidation / Activated Carbon
    - O&M $ 222,000*
  - Activated Carbon only
    - O&M $ 160,000*
  - *excluding analytical

Costs of Alternatives

Natural Attenuation

- **Louisiana AAP Study Site**
  - **$4 million (included substantial research & development costs)**
- **ERDC Estimate for Implementing Natural Attenuation over 20 Years**
  - **$3.24 million**

Sumary

- Fate & Transport - TNT vs RDX
- Remedial Action Alternatives
  - Ex-Situ Treatment Processes
  - Natural Attenuation
- Groundwater Remediation Project Experience

Conclusions

- **Persistance & mobility of RDX drives most groundwater remediation projects**
- **Natural attenuation more likely for TNT than RDX**
- **Natural attenuation most likely in low groundwater-flow-rate aquifers**